THE VOCALITY OF FORK, VIOLIN AND PIANO TONES

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Problem—The immediate purpose of this study has been to investigate the validity of the theory of absolute vocality as it has been set forth by Köhler and others, when applied to tuning forks, piano and violin. If the assumptions as made be true, then we may expect to find a *relative* degree of consistency between the several instruments. A tone of a given pitch should according to the theory have the same vocality, whatever the instrument that produces it, provided the vocality of the over-tones is considered. Kohler[2] assumes first of all that vowels belong to definite frequencies Willis and other investigators also found that vowel character is dependent on frequency. Köhler further assumes that all vowel characters may be defined in terms of the proportion of ū, ō, and ī quality. In other words, these three are most definitely located with ū at the lower end of the scale, ī at the upper and the pure ō sound midway between. As one leaves either end of the scale, the vowel quality characterizing that end becomes less and less prominent and that of the other end increases. Those vowel sounds which his observers definitely located, m, ū, ō, ā, and ē, were of such frequencies that their pitches represent successive octaves in the order named.

Observers—The observers were children from a first grade intermediate school, i. e., from the 7B to the 9A grades inclusive. The ages of the children ranged from 11 to 19, in numbers as follows:

No. of Children	*Age*
11	11
34	12
52	13
54	14
36	15
7	16
2	17
0	18
1	19
2	?

This made a total of 199 children with an average age of 13.3 and a median age of 13. Of these children, 123 had studied some little music outside of that regularly given in the public schools, and 76 had

[1] This research was done, under the direction of Dr. Weiss, at the Ohio State University.

[2] Köhler, Wolfgang, 'Akustische Untersuchungen, II,' Zeitschrift für Psychologie, 1911, 58, pp. 59-140.

not. No definite information could be obtained as to the amounts, so it was merely recorded as 'some' or 'none.' As a general rule, it meant a few lessons on the piano. In addition to the 199 children to whom the three series, i. e., forks, piano and violin, were given, 33 others were given the fork series and the violin series and 26 the fork series only. These results however are not included in the data herein given, as it was desired to have results from the same children for all three series.

Material—The material used consisted of a series of tuning forks including the frequencies 256, 512, 1024, 1280, a piano, and a violin. The experimenter was a performer on both these instruments and was thus able to handle them advantageously for such an experiment.

Method—The experiments were performed in a room in which there were tables and chairs across either end. Approximately twenty children were given the experiments at one time. They were seated at the tables in such a manner that their backs were to the experimenter who played the instruments. The position of each child was about ten feet from the source of the sound.

After the forks had been shown to the children and the method of obtaining a sound from them had been explained, the following instructions were given:

Listen carefully to each fork as it is played and then when I have finished with it, write down opposite the number (serial number, as 1. 2. 3., etc.) the word or vowel it sounds most like to you. I shall play each tone three times. Listen carefully till I have finished and then write down the word. If you can not think of one that exactly fits, put the best thing you can think of; if you can think of none, leave that space blank.

After it was certain that the children understood what they were to do, the first series was presented, giving 256, 512, 1024, 1280, and then a repetition of the same with the order reversed. The same tones were then given in the piano and violin series with the addition of 384 preceding and 1536 following the series as given above. An interval of two or three seconds was allowed after the one tone rung off before it was repeated. Between tones of different pitch sufficient time was allowed to have each child note down the word or sound that he thought represented the tone just given.

The work was marked by interest and splendid cooperation on the part of the children. From the whole number tested, (more than 200) only a very few records had to be discarded because they showed lack of effort or a misunderstanding of instructions on the part of the observers. These were for the most part papers in which the children had tried to give the tonic-sol-fa equivalent for the tone given, which response is one of pitch rather than of vocality.

Results—Obviously in so large a number of records, a great variety of words will appear. The number of actual vowel sounds represented however is much smaller. For example, the words, moon, too, threw, blue and many others all represent the vowel sound ū. Likewise, the words, eat, me, seat, fiend and many others represent the sound ī. Among children we do not find the variety of vowel sounds that we do among adults. This is probably due to the narrower limit of the vocabulary of the child as compared with the adult, as well as the lack of development in finer discriminations of sound. It is often noted that children do not make the fine distinctions in the pronuncia-

tion of words that we find in the average adult. In this instance the sounds which they gave, fall rather naturally into twelve or thirteen groups. In the tables thirteen are given, but the numbers for one group, namely that with the sound short ŏŏ as in took, are very small. These vowel sounds and the number of observers giving such sound for each tone, are recorded in Table I.

TABLE I

NUMBER OF OBSERVERS, VOWEL CLASSES AND VIBRATION RATES FOR FORK. PIANO AND VIOLIN TONES

	ū	ō	ā	au	u	a	ā	ē	i	ai	e	ï	ŏŏ
Fork	who	know	saw	how	hum	fat	far	prey	hit	pine	get	feel	took
256	123	17	15	0	32	2	0	1	1	1	0	1	0
512	88	30	10	7	13	2	0	4	1	1	7	19	3
1024	38	45	4	9	6	1	2	10	10	3	13	45	0
1280	24	16	5	8	9	1	5	3	24	13	13	52	2
1280	17	21	8	8	10	2	4	4	23	18	7	59	0
1024	40	47	13	14	11	0	3	5	9	9	9	19	0
512	74	48	3	10	13	2	2	5	7	2	8	5	1
256	93	26	8	9	23	0	2	4	2	2	7	2	2
Piano													
384	49	56	4	5	13	3	3	4	3	1	3	8	1
256	62	61	5	4	14	2	0	3	0	5	4	4	0
512	15	18	7	4	17	2	6	11	11	11	7	44	0
1024	17	18	4	6	8	2	6	4	12	13	7	53	0
1280	7	18	4	2	8	2	2	7	18	18	10	54	0
1280	6	16	6	1	6	1	2	4	15	14	13	60	0
1024	33	29	8	6	12	4	3	6	8	12	17	11	1
512	29	37	13	4	22	4	4	11	1	4	8	6	1
256	39	59	11	3	17	0	2	2	2	7	7	3	0
1536	8	18	3	3	7	2	2	3	24	6	39	30	0
Violin													
384	23	44	13	6	27	1	3	10	4	5	15	14	7
256	47	57	12	7	21	2	2	11	4	1	2	9	1
512	15	28	3	3	9	3	2	9	7	13	20	61	0
1024	5	7	2	4	6	2	1	8	13	16	14	93	0
1280	10	9	2	5	11	0	3	5	22	20	6	78	0
1280	6	10	4	1	5	3	4	5	17	11	8	100	0
1024	16	15	7	8	11	0	2	13	19	9	14	49	3
512	23	48	15	5	16	1	3	19	8	4	12	14	6
256	33	60	14	11	17	3	6	7	1	12	5	1	4
1536	10	11	3	0	4	1	1	12	20	7	32	63	2

The numbers in the first column indicate the vibration rate of the tone used in each case. The numbers in the remaining columns indicate the number of times the vowel sounds at the top of the columns were given as corresponding with the tones indicated at the left.

For example, when tone 256 was sounded, from the forks, 123 observers reported the vowel sound u, 17 observers the vowel sound o etc. These figures are represented graphically in Figure I.

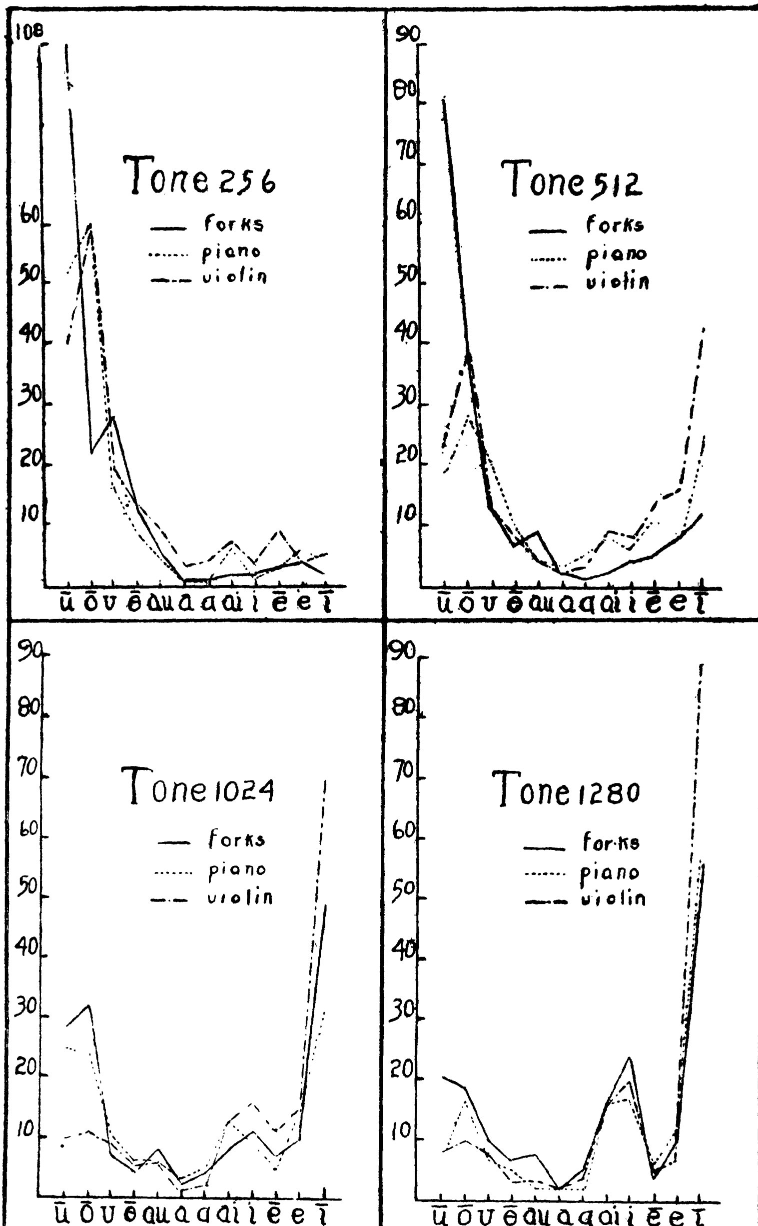

Fig. I—Graphical Representation of Results in Table I. Both trials averaged.

TABLE II

VIBRATION RATE AT WHICH VOWEL WAS MOST FREQUENTLY RECORDED

Vowel	Forks	Piano	Violin	Identity
ū (who)	256	256	256	3
ō (know)	1024	256	256	2
ă (saw)	256	512	256	2
au (how)	1024	1024	256	2
u (hum)	256	512	256	2
a (fat)	512	512 (1024)	256	2
ā (far)	1280	512	256 (1280)	0
ē (prey)	1024	512	512	2
i (hit)	1280	1280	1280	3
ai (pine)	1280	1280	1280	3
e (get)	1024	1024	512 (1024)	3
ī (feel)	1280	1280	1280	3
ŏŏ (took)	512	512 (1024)	512	3

The table reveals that eight of the vowel sounds were placed at the same tone for forks and piano; for eight the forks and violin agree. In six all three agree. Noting the number of times that any particular vowel sound was found throughout the whole series, we find that the numbers for ā, ā, and ŏŏ (Table I) are very small as compared with the other vowel sounds. These vowels might have been combined with other vowels but it was thought best to give actual results without any arbitrary attempt at grouping.

A very large majority of the observers agreed that the sound ū characterizes the tones of the lower end of the scale, and that the sound ī characterizes the higher. Between these limits there is more variation and diversity of opinion, than at the extremes. This fact is shown in Table III, in which is recorded the vowel sound which was given by the largest number of observers for a given tone.

TABLE III

VOWEL SOUND REPORTED MOST FREQUENTLY FOR EACH TONE

Tone	Forks		Piano		Violin	
	I	II	I	II	I	II
256	ū	ū	ū	ō	ō	ō
512	ū	ū	ī	ō	ī	ō
1024	ō and ī	ō	ī	ū (ō)	ī	ī
1280	ī	ī	ī	ī	ī	ī
384			ō		ō	
1536			ē		ī	

I and II refer to first and second trials. For fork 1024, vowels ō and ī were given by the same number of observers (45 each). For tone 1024 when sounded from the piano, ū was given by 33 observers and ō by 29.

It was thought desirable to calculate the consistency[3] or reliability of the vowels assigned to the various vibration rates. The formula $C = (b^2 + d^2)/T^2$ was used. For example, if tone 256 is sounded ten times, and the vowel *ū* is reported three times, the vowel *ō* four times, and the vowel *àu* three times, an application of the formula gives $C = (3^2 + 4^2 + 3^2)/10^2$ or reduced, $C = .34$. If the same vowel is given each time, we get $10^2/10^2$, a maximum consistency of $C = 1.00$, if a different vowel is recorded each time or by each observer we get 1^2...... 10 times or $10/10^2$, a minimum of $C = .10$. In Table IV are recorded the consistencies for each tone and for each instrument.

TABLE IV

CONSISTENCY FOR EACH VIBRATION RATE

	256	512	1024	1280
Fork	.34	.23	.14	.13
Piano	.17	.08	.09	.11
Violin	.15	.11	.17	.23

THEES FIGURES REPRESENT THE AVERAGE OF THE CONSISTENCIES AS CALCULATED FOR THE FIRST AND SECOND TRIALS—FIG. II SHOWS THE COMPARISONS MORE CLEARLY

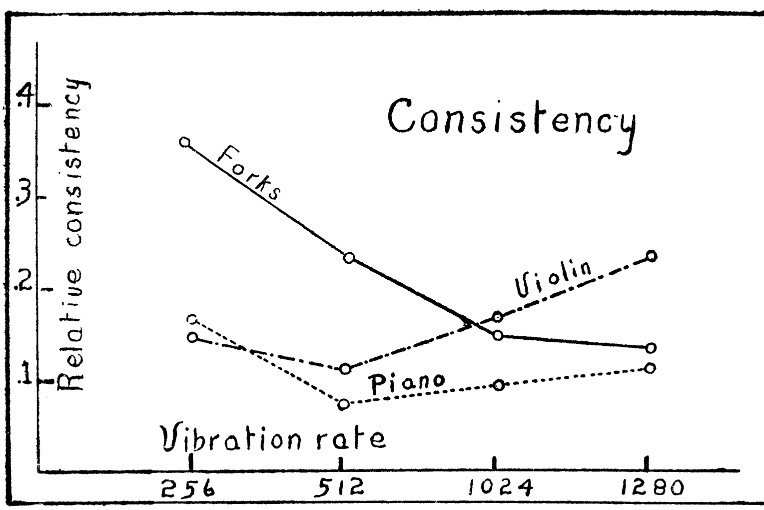

Fig. II—Graphical Representation of Table IV.

Among 200 observers, with all the possibilities of vowel sounds before them, it is not surprising that we do not get a greater con-

[3] In conformity with a similar article by A. P. Weiss it was thought best to adopt this formula.

sistency. We find that the curves of consistency for the forks and the piano are approximately the same shape, but in the curve representing the tones as given by the violin, there is a rise at the upper end, instead of the lower. Miller[4] has found that the lower tones when sounded from the violin have weak fundamentals. Furthermore, the resonance of the body of the violin is such that it emphasizes the higher tones and their partials. The lowest tones on the violin are lower than the fundamental resonance of the violin body. On the average, the consistency for the forks is greatest, the violin second, and the piano least.[5] The consistency or agreement between the two trials is also greatest for the forks, for the violin second, and for the piano least (Table III).

Another interesting result is that gained by comparing the vowels given for the two lowest tones and those for the two highest tones of the series. Fifty-three per cent of the observers gave either ū or ō as the vowel representing the vocality of the tone 384 as sounded by the piano, whereas 62 per cent gave these vowels for the vocality of tone 256. This fact shows a discrimination of the lower vowel quality of the tone 256 as compared with tone 384. Likewise, 37 per cent of the observers gave the five vowels representing the highest vowel quality,[6] when tone 1024 was sounded, whereas 52 per cent of the observers gave these high vowels when tone 1280 was sounded. This shows a discrimination of the ī vowel quality as the upper limit of the scale is approached.

In the violin series, 59 per cent of the observers gave the vowels of the lower end of the series after tone 384 was sounded, whereas 74 per cent gave these same vowels to the tone 256. This shows a discrimination of the lower vowel quality of the tone 256. Likewise, at the upper end of the scale, 50 per cent of the observers gave the ī, āī, or ī vowel sounds to the tone 1024, whereas 62 per cent gave these vowels to the tone 1280. This shows a discrimination of the increase of the ī quality as the upper limit of the scale is approached.

The addition of the two tones to the piano series and the violin series furnished a test of the children's ability to recognize the change in vowel character, when the change was not a part of the progressive series. A study was made of each individual's response to the change, i. e., whether he changed from a lower vowel sound to a higher, kept the same vowel for both tones, or changed from a higher to a lower vowel sound. These results are given in Table V.

[4]Miller, Dayton, Clarence—The Science of Musical Sounds, 1916, p, 197.

[5]The question as to whether the consistency of different instruments changes for different vibration rates is an interesting problem, but one for which this data is insufficient.

[6]These figures were obtained by adding the number of au, e, ī, i, and ai vowels given for the tone 1024 (or 1280 as the case may be). These vowels are given the greatest number of times at either 1024 or 1280, when sounded from the piano. (Table II).

TABLE V

VOWEL CHANGES RECORDED WHEN TONE CHANGE WAS NOT A PROGRESSIVE ONE

Change	Lower to Higher	Same for Each	Higher to Lower
Piano			
From 256 to 1536	66%	18%	16%
From 384 to 256	18%	61%	21%
Violin			
From 256 to 1536	72%	21%	7%
From 384 to 256	19%	35%	46%

The results show that when the change in interval is from 256 toward 1536, a large per cent of the observers changed the vowel from lower to higher as would be expected. A small per cent of the observers kept the same vowel or changed from a higher to lower. On the other hand when the change in interval is from 384 to 256, (a small change when compared with the preceding one) a high per cent of the observers recorded the vowel quality of the two tones as the same, a small per cent recorded a change from higher to lower (the true change) or from lower to higher. The number recording a change from higher to lower was of course greater than those recording the opposite change. These comparisons are made on the basis of the piano series. In the violin series, the results are practically the same, except that in the change from 384 to 256, a higher per cent of the observers made a vowel change from higher to lower (the correct change) than those who kept the same vowel for both tones, as was the case in the piano series. This does not alter the conclusions to be drawn from these results however. The results simply mean that the observers discriminated a much greater change in vocality between tone 256 and tone 1536 than between tone 384 and 256.

Conclusions—The results of this study warrant the following conclusions:

1. There is unquestioned evidence that there is some degree of consistency in the vocality assigned to tones, whether produced by forks, piano or violin. This means that the vocality is a factor associated with pitch, but not one of absolute pitch.

2. The vowel quality ranges from the ū sound at the lower end up to the ī quality at the upper end of the scale, with a wide variety of vowel characters between the two, which become more and more like these extremes as the upper or the lower end of the scale is reached.[7] The great majority of the observers agree as to the location of the ū and the ī vowel sounds.

3. The degree of consistency of the vowels assigned to the various vibration rates is greatest when the tones are produced by the tuning forks. This is probably due to the absence of overtones, the tones from the tuning forks being relatively much simpler or purer than the same tones produced by the piano or the violin The vocality of any

[7] Titchener, E. B. 'Beginner's Psychology,' p. 52.

given tone depends not only upon the fundamental tone, but also upon the several overtones, and the intensity of each.

4. The results of this experiment agree with those of Köhler first, in that the vowel characters ū and ī are much the easiest to locate. Secondly, the location of the ō sound is somewhere near the same, 512 (Köhler located it between 520 and 530). Thirdly there is a gradual decrease of the ū quality and an increase of the ī quality as one proceeds from the lower to the upper end of the range. However these results do not agree with the assumption that the vowel character is dependent on frequency. Were this true the dominant vowel quality should be the same, whatever the instrument used. One of the principal differences obtained by using the several instruments, is the change in the number and intensity of the overtones present. We find that there is a shift in the location of some vowel characters with a change in instrument. Köhler reported that he had trouble with the observers, due to their unfamiliarity with the tuning forks. In the present experiments this was not true. Greater consistency was obtained with the tuning forks than with either of the instruments. Köhler suggests that the vowel character may be found not only at a given frequency, but at those frequencies which are in immediate proximity to it. He makes his theory of vowel character comparable in this wise to the resonance theory of Helmholtz.

No attempt was made in this study to point out a definite location for any given vowel sound, but the results do not point in that direction. The pitch of a vowel is not nearly so absolute as is assumed by Köhler. The order of vowels found as related to pitch range was indeed that obtained by Köhler, but the results would rather warrant the following assumption.

There is at the lower pitches a quality, which corresponds to the vowel ū of the speaking voice, and there is at the upper pitches a quality, which corresponds to the ī sound of the speaking voice. These might be referred to as a mellowness or a shrillness, as is done by Meyer, which we merely represent by means of the vowels. In between these limits there are many other characteristic sounds, which may resemble the ū or the ī or may be of such a character as to be identified with neither. These we indicate by means of other vowels which are formed in such manner as to have a mellowness or shrillness between the designated limits. The fact that, as Miller found, starting with the pure ō sound, one may by slowing down the movement of the graphophone produce a sound that becomes less like the ō and more like the ū, or by speeding up the movement, produce a sound that becomes less like the ō and more like the ī, does not necessarily imply that the vowel character is a function of the vibration rate of the fundamental only. The presence of upper overtones of high intensity will of necessity bring into the compound more of the ī element. This is shown particularly with the experiments on the violin tones. The presence of strong overtones whether high or low, will raise the vowel character. We accordingly find that when the tones are produced by tuning forks where the presence of overtones is comparatively unimportant, that the ū sound or quality predominates and that even with the higher pitches, the amount of the ī quality does not reach that of these same pitches when sounded from the piano or more especially the violin.

If a small mouthed bottle be held under a stream of water and allowed to fill, the tone produced by the water passing through the mouth rises in vowel quality as well as in pitch. This closing up of a larger cavity to a smaller produces the change from the mellow to the shrill quality, which we designate by means of the vowel equivalents. This is in some measure the same as what Watt[7] calls tone-volume, although he later defines vowels as "(partial) sounds of a somewhat indefinite pitch which lies about the point of range of pure tones of definite pitch where the greatest resemblance to these vowels is to be found." It seems, however, that it is not the slight variation in fundamental pitch that is so important, as the effect that the change in the intensity of the overtones has upon the whole, and thus upon the vowel character.

[7] Watt, Henry J., 'The Psychology of Sound,' p. 233.